Unravelling molecular and physiological mechanisms of foliar temperature regulation during photoinhibition and its impact on retrograde cell death signalling and acclimatory responses in Arabidopsis.

Climate changes and global warming lead to enhanced evapotranspiration and desertification of vast areas of the world. High light, heat and drought stress have become the most relevant limiting factors to crop productivity. Plant responses to these adverse conditions promote stomatal closure and lead to increased photorespiration and oxidation-induced damage processes. In plants failure to utilize or dissipate absorbed light leads to the rapid foliar temperature increase, generation of reactive oxygen species (ROS), radicals, and triplet state excited pigments as well as changes in redox state of the plastoquinone pool. Accordingly, plants possess a suite of photoprotective mechanisms of excess light response, e.g. nonphotochemical quenching (NPQ), which is used to dissipate energy produced in excess as heat. The issue of foliar temperature regulation during photosynthesis and photoinhibition and its physiological relevance on the acclimation/adaptation has not been considered before. Our previous studies showed a relationship between foliar temperature and changes in molecular cell death markers, as well as biochemical, and physiological traits, which indicates that measuring the foliar temperature gradient generated by alterations in light absorbed in excess can be used for associating all these traits with yield and productivity of crops.

Our studies revealed that cell death regulators LESION SIMULATING DESEASE 1 (LSD1), ENHANCED DESEASE SUSCEPTIBILITY (EDS1) and CYSTEINE RICH RECEPTOR-LIKE KINASE 5 (CRK5) are involved in high light and drought signalling pathways. LSD1 negatively regulates simultaneous drought and high-light stress tolerance and acts in an EDS1-dependent manner, whereas CRK5 acts as a negative regulator of cell death and significantly affects stomatal conductance and water-use efficiency (WUE). Moreover, we have recently described two transcription factors, CHLOROPLAST IMPORT APPARATUS 2 (CIA2) and CHLOROPLAST IMPORT LIKE (CIL), which negatively regulate foliar thermotolerance and are required for optimal NPQ, chloroplast biogenesis and proper formation of trans-thylakoid proton. All these proteins seem to play a role in plant acclimation to conditions promoting stomatal closure, which is directly related to foliar temperature.

We suggest the following research hypothesis: Regulation of cellular and foliar temperature by energy quenching mechanisms (NPQ) in chloroplasts is essential for cell death retrograde signalling, photooxidative stress and acclimation responses.

In order to get a closer insight into these processes we plan use plant lines with disrupted activity of the above mentioned proteins (as well as double and triple mutants) and implement extensive experimental setup based on variable light conditions combined with variable temperature and water supply. We are going to measure foliar temperature and calories produced by leaves during photosynthesis and its inhibition and correlate it with the level of hormones, ROS, stomatal aperture, cell death as well as WUE and yield. We also plan to analyse chlorophyll fluorescence parameters, electrical signalling and dynamic changes in downstream gene expression under variable conditions using high-throughput transcriptomics based on in-house prepared cDNA libraries. The study will involve both local and systemic leaves to check if induction of systemic acquired acclimation will cause any changes in foliar temperature regulation in comparison to local response. Moreover, since we have recently described a dual chloroplast-nuclear localization of CIA2/CIL, we plan to check if CIA2/CIL signalling overlaps SAL1/PAP retrograde pathways during plant acclimatory responses to heat and drought. The SAL1-PAP signalling was previously proposed as a chloroplast retrograde pathway integrating light and hormonal signalling in plants.

Getting a closer insight into cellular mechanisms underlying adjustment of foliar temperature into variable conditions would help to understand to what extent it influences cell death chloroplast retrograde signalling mechanisms, which contribute to growth, development, stress and acclimation responses in plants.